# THE PREGLACIAL VALLEYS OF THE MISSISSIPPI AND ITS TRIBUTARIES.

It is the purpose of this paper to bring together such data as are available on the subject of preglacial drainage lines, in the northern part of the Mississippi basin. It is thought that such a presentation will aid in drawing inferences concerning several important questions connected with glaciation; among which are the preglacial altitude of the region, the differential crust movements, and the effect of glaciation in enlarging and deepening valleys. It will be mainly a contribution of facts. The questions upon which these facts have a bearing need the full light of these and other data before inferences of much value can be drawn.

This district has, in some respects, advantages not possessed by other districts. (1) It has a driftless area in which the breadth and depth of large preglacial valleys can be accurately determined. The location of this driftless area is particularly fortunate, being over the line of so prominent a valley as the Mississippi, a valley which crosses drift-covered areas both above and below the driftless area. (2) In some parts of the glaciated region the oldest drift sheets are not well represented, and it often becomes difficult to decide whether a given valley was cut to its present depth in preglacial time or has been deepened in inter-glacial or post-glacial times. In the region here discussed some of the valleys are filled with the oldest drift sheet of which we have knowledge, and their floors have not since been subject to the scour of streams. We can, therefore, confidently place their excavation before the first ice invasion. (3) In this region the valleys of some of the main arteries of preglacial drainage are found running parallel with the longer axis of one of the deepest lake basins, the basin of Lake Michigan. A study of the contours of these valleys, combined with a study of the lake basin should help to an understanding of the influence of the ice-

sheet in giving this basin its low altitude. The slope of preglacial valley floors will throw light upon differential crust movements which have affected the basin. Unfortunately we have as yet very few data from Wisconsin, a district which should furnish many important data when the reports of its borings are collected and its preglacial drainage lines worked out.

### COURSES OF THE MAIN PREGLACIAL DRAINAGE LINES.

Concerning the course of the Mississippi above the mouth of the Minnesota River very little is known. It is probable, however, that its drainage area was about as great as that of the present stream. From the mouth of the Minnesota southward to the mouth of the Wapsipinnicon River below Clinton, Iowa, a distance of about 300 miles, the present stream follows the line of the preglacial, the only deviations from that line being slight encroachments on the bluffs of the old valley, as at Fulton, Illinois, where a rocky point belonging to the old west bluff has been cut off by the present stream. Below the mouth of the Wapsipinnicon, the present stream for a distance of forty miles (to Muscatine, Iowa) is in a new course. The bordering districts are heavily covered with drift and it is not an easy matter to determine the course of the old valley. I expressed the opinion, some three years ago, that the course was southeastward through the Green River basin to a bend of the Illinois River near Hennepin.[1] This opinion was based upon the existence of a low tract of country connecting the Mississippi with the Illinois along the north border of the Coal Measure formations. It has since been discovered by Professor J. A. Udden that a similar tract of country more completely concealed by the drift follows the northern border of the Coal Measure area westward and southwestward from the mouth of the Wapsipinnicon through Scott and Muscatine counties, Iowa, to the old valley below Muscatine. Which of these courses was taken by the preglacial upper Mississippi is being made a matter of special investigation by Professor Udden, and we look for an early publication of the results of his investigations. He informs me that the lowest

[1] Proc. A. A. A. S., Rochester Meeting, Vol. XLI., 1892, p. 176.

altitudes yet brought to light by borings are along the line leading through eastern Iowa, but that the line leading southeastward to the Illinois has been less perfectly tested by borings and hence may contain a channel equally deep.

From Muscatine to the Mississippi embayment of the Gulf above Cairo, Illinois, the present line of the Mississippi is nearly coincident with that of the preglacial line. The most important diversion is at the lower rapids just above Keokuk, where for a distance of twelve miles the present stream is cutting a new valley parallel to and slightly east of the preglacial course. There are slight diversions of the present stream into the edge of the bordering bluffs at two points below St. Louis, similar to the one noted above, at Fulton. One of these is at Fountain Bluff and the other at Thebes, Illinois. The preglacial course is plainly traceable around the rocky points which the present stream cuts off, and is utilized at flood seasons in both cases.

In the district between St. Paul, Minnesota, and the mouth of the Illinois the eastern tributaries of the Mississippi, with the exception of the Wisconsin River, were very small, owing to the existence of a large parallel valley traversing southern Wisconsin and western Illinois, as shown below. Western tributaries of the Mississippi appear to have drained a wide area but their courses have not as yet been worked out, for the region is very heavily covered with drift, and a large number of borings will be necessary to establish, even approximately, the course of preglacial drainage. It is certain that the present and preglacial systems of drainage are coincident in but a few places.

The preglacial Rock River drainage basin apparently extended to the Mineral Ridge axis on the northwest and to the Niagara escarpment on the east. The course of the main line of drainage was probably along the axis of the trough west of the Niagara escarpment. Whether the drainage of this trough was then divided, as at present, between Green Bay and Rock River, the writer is not prepared to judge, for this is a district which has not been personally examined and the published data are scarcely adequate to warrant a decision.

Rock River follows nearly its preglacial course from the Kettle

moraine in southern Wisconsin, southward to the mouth of the Kishwaukee, a few miles below Rockford, Illinois, where it turns to the southwest and follows a new valley to the Mississippi.[1] The preglacial course of the river is plainly traceable southward from the mouth of the Kishwaukee across eastern Ogle county to the vicinity of Rochelle, the drift being insufficient to fill the old valley to the level of the bluffs. From Ogle county southward across Lee and Bureau counties to the bend of the Illinois River at Hennepin, borings have shown the presence of a deep channel. Several have gone to depths below that of the rock surface a few miles to the west. Only one of these borings, the artesian well at Princeton, Illinois, has reached the rock floor. This shows a drift filling of 440 feet, and probably strikes the deepest part of the old valley, the rock floor being as low as at any point yet found in the course of the whole channel. There can scarcely be a doubt that the preglacial course of Rock River was southward along this line to the Illinois, and thence to the Mississippi, though we have as yet no borings, except the one at Princeton, which test its deepest portion at any point between the Wisconsin line and bend of the Illinois.

The courses of the preglacial tributaries of the Rock-Illinois are known only in a few instances, owing to the great amount of drift which conceals them. The Pecatonica Valley which enters from the west, just below the Wisconsin line, is mainly in a preglacial course and so are its main tributaries, Yellow Creek and Sugar River. The Kishwaukee is largely in a new valley and enters the Rock River Valley through a gorge at its mouth. The upper portion of the Illinois, including its headwater streams —the Fox, the Des Plaines and the Kankakee—are all in postglacial valleys. They cross a somewhat elevated limestone district which, like the Niagara escarpment to the north, seems to have formed the preglacial watershed between the Rock-Illinois drainage basin and the basin now occupied by Lake Michigan. They thus bring to the present Illinois the drainage of a large district which formerly discharged into the Lake Michigan basin.

[1] Changes of drainage in the Rock River basin in Illinois, by FRANK LEVERETT, Proc. A. A. A. S., Madison Meeting, Vol. XLII., 1893, p. 179.

Southward from Hennepin the drift deposits are so heavy that it has been found impossible to map out the courses of preglacial drainage. A basin or expansion of the valley just north of the mouth of the Sangamon River, and a very low altitude of rock surface for some distance to the east of this basin is thought to indicate the point where a large preglacial tributary enters from the east. The Sangamon drains a region which probably then, as now, discharged to the north, perhaps joining this large eastern tributary. South from the Sangamon River the preglacial tributaries were about the same size as the present, there being a well-defined rock divide between the headwaters of the south fork of the Sangamon and the lower portion of the Illinois. The western tributaries of the Illinois were probably small as were the present ones, owing to its nearness to the Mississippi.

The present Wabash River follows a preglacial drainage line from its bend near Covington, in western Indiana, southward to the Ohio River. The stream is in a new valley for a few miles above Covington but is again in a preglacial valley in the vicinity of La Fayette. It is probable that this preglacial valley leads westward past Oxford, Indiana, and thence south to the preglacial Wabash near Covington. From near Delphi, Indiana, to its source the Wabash is mainly in a new course. The headwater portion of the streams forming the preglacial Wabash may prove to have been in the Lake Michigan basin. But if so the connection with the Wabash is through a very much narrower trough than that occupied by Lake Michigan. Borings at North Judson, Winamac and Monticello, Indiana, situated near the line connecting the head of Lake Michigan with the preglacial valley at La Fayette, go to a level about 100 feet below the surface of Lake Michigan before entering rock. But within a few miles east of this line, rock ledges have an altitude as great as the surface of Lake Michigan, while immediately west of this line they rise 90–125 feet above that level. This trough cannot have, in the vicinity of Monticello, a breadth of more than ten miles. Monticello is situated near the middle of the trough. The probabilities are, therefore, against the existence of a much deeper channel in it.

Borings have been made at frequent intervals westward and northwestward from this trough across northwestern Indiana and northeastern Illinois and none of them show so low a rock surface as this line presents. They usually enter rock above the level of Lake Michigan. There seems, therefore, no ground for suggesting a southward or southwestward outlet of the Lake Michigan basin further west than the line which leads from the head of the lake to La Fayette, Indiana. Furthermore this seems the most probable line for a channel, since it follows nearly the western edge of the soft Devonian shales, where degradation would naturally proceed more rapidly than in the firm and resistant limestone ledges to the west.

The tributaries of the Wabash in its lower portion follow, to a large extent, their preglacial courses. The eastern tributaries drain a driftless region in Indiana, while the western drain a region thinly clad with drift in southern Illinois. From the latitude of Terre Haute and St. Louis southward, the Mississippi and Wabash seem to have divided the drainage of southern Illinois in preglacial times, about as they do at present.

The Ohio River seems to have been greatly enlarged by the ice invasion. But little study has been given the lower course of this stream. It is probable, however, that from southern Ohio to its mouth it follows nearly the preglacial line, since that portion was encroached upon but little by the ice-sheet. The upper course from eastern Ohio northward seems to have discharged to the Lake Erie basin.[1] The Muskingum Valley of eastern Ohio is thought by Professor W. G. Tight, to have discharged northwestward in preglacial times, instead of southward into the Ohio.[2] The data collected by Professor Tight make it appear quite probable that this valley was a tributary to the Scioto basin. The view that it continued across that basin into the Wabash seems less fully sustained.

[1] For a presentation of the evidence see Amer. Jour. Sci., Vol. XLVII., 1894, pp. 247–283. The paper referred to contains references to the literature of the subject, which is already quite extensive.

[2] A contribution to the knowledge of the Preglacial Drainage of the Ohio, W. G. TIGHT, Bull. Sci. Lab., Denison University, Vol. VIII., pp. 35–61. With two plates. Granville, Ohio, 1894.

ELEVATION AND SLOPE OF PREGLACIAL VALLEY FLOORS COMPARED WITH PRESENT STREAMS.

*The Mississippi Valley.*—In this discussion we assume for convenience that the upper Mississippi found its continuation from the mouth of the Wapsipinnicon through Scott and Muscatine counties, Iowa, to the preglacial valley below Muscatine. On a subsequent page we discuss the comparative elevations and slopes of the valley floors of the upper Mississippi and the Illinois.

In preparing the table which follows some difficulty was found in deciding upon distances. In the portion above Cairo there are few oxbows or other deflections from a direct course, hence the distances at high and low water stages are not greatly different, and the high water distance is usually taken. In the portion below Cairo the oxbows and deflections of the stream are numerous. The low water stage involves, therefore, a much greater distance than the high water stage. The distances given are the low water route. They are taken from *Dana's Manual.* The distance from Cairo to Memphis at high water stage is about 150 miles, or only two-thirds that of the low water stage. Between Memphis and the Gulf the distance at high water is estimated to be but 500 miles, or 350 less than the low water stage. Taking the direct course, the rate of fall between Cairo and Memphis at high water stage is 8.24 inches per mile, while between Memphis and the Gulf it is 5.23 inches per mile. Some interesting differences in the rate of fall between certain points at high water and low water stages appear in the upper Mississippi. Thus for a few miles above each of the rapids there is a greater fall at flood stage than at low water. The low water stage is below the usual rate of fall, owing probably to the barrier presented by the rock floor at the head of the rapids. This barrier has little effect upon high water stages, and the descent of the stream is, therefore, nearer the normal.

It is probable that the borings at Fort Snelling, St. Paul, Dubuque, Sabula, Fort Madison, Bellefontaine and East St. Louis, enter the deep part of the preglacial channel, though they may not mark the very lowest limit of erosion. The other borings probably strike shelves bordering the channel when not on

RATE OF FALL OF THE PREGLACIAL ROCK FLOOR AND THE PRESENT MISSISSIPPI FROM FORT SNELLING, MINNESOTA, TO THE GULF OF MEXICO.

| Location | Dist. Miles | Low Water A. T. | High Water A. T. | Fall per Mile L. W. | Fall per Mile H. W. | Rock Floor A. T. |
|---|---|---|---|---|---|---|
| | | Ft. | Ft. | In. | In. | Ft. |
| Ft. Snelling, Minn. | 0 | 686 | ..... | ..... | ..... | 486[1] |
| St. Paul, Minn. | 6 | 683 | 702 | 6.00 | ..... | 483[1] |
| Lake City, Minn. | 55 | 658 | ..... | 5.45 | ..... | 495[2] |
| La Crosse, Wis. | 68 | 628 | 643 | 5.30 | 5.75 | 504[3] |
| Prairie du Chien, Wis. | 60 | 604 | 623 | 4.80 | 4.00 | 492[3] |
| Dubuque, Iowa | 55 | 585 | 607 | 4.14 | 3.49 | 453[3] |
| Sabula, Iowa | 36 | 572 | 592 | 4.33 | 5.00 | 429[4] |
| Fulton, Ill. | 16 | 566 | 587 | 4.50 | 3.75 | 465 |
| Le Claire, Iowa (New Ch.) | 20 | 562 | 576 | 2.40 | 6.60 | 550 |
| Rock Island, Ill. (New Ch.) | 16 | 542 | 560 | 15.00 | 12.00 | 530 |
| Muscatine, Iowa (New Ch.) | 24 | 531 | 547 | 5.50 | 6.50 | 506 |
| Near Wilton, Iowa (Old Ch.) | ..... | ..... | ..... | ..... | ..... | 400–[5] |
| Mouth of Iowa River | 18 | 523 | 539 | 5.33 | 5.33 | 445– |
| Burlington, Iowa | 24 | 511 | 527 | 6.00 | 6.00 | 430– |
| Ft. Madison, Iowa | 18 | 502 | 518 | 6.00 | 6.00 | 365[6] |
| Near Montrose (Old Ch.) | ..... | ..... | ..... | ..... | ..... | 374[7] |
| Montrose, Iowa (New Ch.) | 9 | 500 | 514 | 2.66 | 5.35 | 490 |
| Keokuk, Iowa | 12 | 477 | 494 | 23.00 | 20.00 | 470 |
| Quincy, Ill. | 38 | 458 | 476 | 6.00 | 5.68 | 413[8] |
| Hannibal, Mo. | 17 | 450 | 467 | 5.64 | 6.35 | 362[9] |
| Louisiana, Mo. | 25 | 437 | 453 | 6.24 | 6.72 | 380–[10] |
| Mouth of Illinois River | 68 | 403 | 422 | 6.00 | 5.47 | ? |
| Bellefontaine, Mo. | 17 | 402 | 420± | 0.70 | 1.40± | 295[11] |
| East St. Louis, Ill. | 24.3 | 380 | 414 | 10.86 | 2.96± | 284[12] |
| E. Carondelet, Ill. | 6 | 377 | 412 | 6.00 | 4.00 | 330 |
| Fountain Bluff, Ill. | 100 | 313 | 357 | 7.68 | 6.60 | 300[13] |
| Thebes, Ill. | 40 | 291 | 339 | 6.60 | 5.40 | 280[13] |
| Cairo, Ill.[14] | 35 | 270 | 321 | 7.20 | 6.16 | ? |
| Memphis, Tenn.[15] | 233 | 183 | 218 | 4.48 | 8.24 | ..... |
| Mouth of river | 855 | 0 | ..... | 2.56 | 5.23 | ..... |

[1] N. H. WINCHELL: Amer. Geol., Aug., 1892.

[2] Geol. of Minnesota, Vol. II., p. 17.

[3] CHAMBERLIN and SALISBURY: Sixth An. Rept. U. S. G. S., p. 223.

[4] Data given by W. R. Oake, Ex-Mayor of Sabula.

[5] This point is about ten miles from Muscatine and fifty miles from Fulton making the old course about the same length as the new one. A well at this point, reported by Professor Udden, failed to reach rock at elevation 400 feet A. T.

[6] C. H. GORDON: Geol. of Iowa, Vol. III., 1893, p. 246. A well one-half mile north of Ft. Madison reaches a level about 365 feet A. T. without entering rock. The channel may, therefore, be deeper than that shown by the Ft. Madison wells.

[7] Beck's Artesian Well, Geol. of Iowa, Vol. III., p. 247.

[8] Bridge piers rest on a rock shelf 35–40 feet below low water (G. K. Warren).

[9] Data concerning channel piers furnished by W. S. Lincoln, Chief Engineer of Wabash Railroad, St. Louis, Mo.

slopes near the border of the valley. It certainly should not be assumed that they have entered the deepest part of the channel.

If the borings at the points named reach the lowest part of the channel, we may estimate the rate of descent of the rock floor between St. Paul and St. Louis. Between St. Paul and Sabula, a distance of 274 miles, the descent is only 57 feet or 2½ inches per mile. Between Sabula and Fort Madison, a distance of about 140 miles, the descent is 64 feet or about 5½ inches per mile. Between Fort Madison and East St. Louis, a distance of about 210 miles, the descent is about 80 feet or 4.57 inches per mile. These data indicate much less descent from St. Paul to Sabula than below Sabula. We can hardly suppose that a much deeper portion of the channel occurs opposite Sabula, for the well at this village was sunk in the middle of the valley. It seems probable, therefore, that the valley floor has been slightly warped, so that its altitude at Sabula is higher, or at St. Paul lower, than it was when the stream flowed upon the rock floor. To completely demonstrate such a warping, it will be necessary to make certain that the low altitude at Fort Snelling and St. Paul is not due to local deepening, such as may have been produced by glacial water falls, or by subglacial erosion by water or ice. At Sabula no such agencies could have been operative.

The descent in the rock floor, from Sabula to East St. Louis, is not markedly different from that of the present stream, being 145 feet, where the present stream falls 192 feet. If we reduce the descent of the present stream at the two rapids to the average rate for the river it lessens the difference thirty feet, leaving but seventeen feet difference in a distance of about 350 miles,

[10] Bed of present stream is 380 feet A. T. (G. K. Warren).

[11] Mo. Riv. Com. Rept. for 1890. The low water altitude here given is on the Missouri.

[12] Data concerning depth to rock at bridge piers, furnished by Robert Moore, C. E., St. Louis, Mo.

[13] In new channel (G. K. Warren).

[14] Low water varies from 267–279 feet A. T. (Gannett).

[15] Tertiary clays set in at bed of river and extend nearly to sea level (Reports on Memphis water supply, by J. M. STAFFORD and LAWRENCE JOHNSON, issued by Artesian Water Co. of Memphis).

or but six-tenths of an inch per mile. Under present conditions the river will soon remove the rapids and reduce its rate of fall to that of the rock floor, if not, to a lower rate.

*The Missouri Valley.*—For purposes of comparison with the Mississippi Valley, and valleys further east we introduce at this point a few statements concerning the Missouri Valley, followed by a table showing the elevation and slope of the valley floor and of the present stream, from Sioux City to the mouth of the stream. The table is compiled chiefly from data given in the annual reports of the Missouri River Commission for 1890 and 1892. We are indebted for additional data to Mr. George S. Morison of Chicago, chief engineer in the construction of several bridges across the Missouri. We are also indebted to Professor J. E. Todd, State Geologist of South Dakota, for suggestions, both published and unpublished, concerning the history of this youthful but somewhat overgrown tributary of the Mississippi.

The researches of Professor Todd and others have developed the fact that the present course of the Missouri, through the Dakotas is independent of preglacial valleys, and dependent upon the position of the ice margin. Its course along the boundary of Nebraska is considered by Professor Todd to antedate but little the late ice invasion which was marked by the Altamont moraine. He finds evidence that Lake Cheyenne persisted, in eastern Nebraska, southeastern Dakota and southwestern Iowa, to the beginning of the glacial period[1] and infers a very low altitude for the region up to that time, one not calculated for deep erosion of valleys. He writes that he has not yet found a clear case along the Missouri Valley, of excavation prior to the glacial deposition. In examinations of the rock surface exposed in sinking the piers of the bridges at Blair and Omaha, he failed to discover evidence of glacial action. Alleged glacial deposits in the valley lower down, as at St. Charles, Missouri, he thinks capable of another interpretation. The entire valley may prove to be more recent than the Kansan stage of glaciation.

[1] Evidence that Lake Cheyenne continued till the Ice Age, by J. E. TODD, Proc. A. A. A. S., Cleveland Meeting, Vol. XXXVII., 1888, pp. 202, 203.

The reports of the Missouri River Commission show, in profile, the results of a series of test borings across the entire breadth of the valley at Sibley, Missouri.[1] The rock floor nowhere stands more than sixty-five feet below low water, or little, if any, below the scour of the present stream. Borings at St. Charles, Missouri, on the very border of the Mississippi Valley, apparently test the rock floor of the Missouri in its lowest part, and find it but seventy feet below low water.[2] Only twenty miles below St. Charles at Bellefontaine, the bridge shows at its north pier a rock floor 107 feet below low water at this point. The rock floor is perhaps still lower between there and the Mississippi channel four miles to the north, there being a slight northward descent in the rock floor at the north pier. The available data seem to indicate that where the Missouri joins the Mississippi, the latter has a channel forty to fifty feet or more deeper than the former.

ALTITUDES OF THE ROCK FLOOR AND PRESENT MISSOURI AT BRIDGES BETWEEN SIOUX CITY, IOWA, AND THE MOUTH OF THE STREAM.[1]

| Location | Dist. Miles | Low water A. T. | Fall per mile | Rock Floor, A. T. |
|---|---|---|---|---|
| | | Ft. | In. | Ft. |
| Sioux City, Iowa | 0 | 1076 | | 950 ± |
| Blair, Nebraska | 102.8 | 986 | 10.50 | 934–944 |
| Omaha, Nebraska | 35.5 | 963 | 7.77 | 839–890 |
| Plattsmouth, Nebraska | 25.5 | 943 | 9.41 | 872 |
| Nebraska City, Nebraska | 25.9 | 910 | 15.29 | 750[2] } 815–855 } |
| Rulo, Nebraska, | 70.2 | 843 | 11.45 | 715[3] |
| White Cloud, Kansas | 12.1 | 833 | 9.90 | 772 |
| St. Joseph, Missouri | 46.4 | 794 ± | 10.08 | 743 |
| Leavenworth, Kansas | 57.2 | 745 | 10.28 | 688 — |
| Kansas City, Missouri | 31.1 | 721 | 9.26 | 660–680 |
| Randolph Bluffs, Missouri | 4.0 | 713 | 24.00 | 631 |
| Sibley, Missouri | 36.7 | 690 | 7.52 | 625–655 |
| Glasgow, Missouri | 102.5 | 594 | 10.23 | 550 |
| Booneville, Missouri | 31.7 | 570 | 9.08 | 513 |
| St. Charles, Missouri | 177.7 | 420 | 10.13 | 350 |
| Bellefontaine, Missouri | 21.7 | 406 } 402 } | 7.79 | 295 |

[1] Report of Missouri River Commission for 1889–90, Appendix XX. of the Annual Report of the Chief of Engineers for 1890, p. 3379, Plates V. and VI., Government Printing Office, Washington.

[2] Loc. cit., p. 3377 and Plates I. and II.

*The Illinois Valley.*—The data concerning the rock floor from the bend of the Illinois northward, along the preglacial valley are very meager. Professor Chamberlin reports a boring at Lake Koshkonong, Wisconsin, which failed to reach rock at 450 feet. A. T. A boring at Janesville, Wisconsin, enters rock at 530 feet A. T. and several at Rockford, Illinois, at 529–588 feet A. T. But these are all very near the west bluff and, in all probability, enter rock much above the level of the deepest part of the old channel. It is in the portion of the old valley occupied by the Illinois that the rock floor is best known.

We begin the table at the head of the present Illinois, that the contrast between the new and the old valley may be brought out. For the low water altitudes and for the measurement of distances we are indebted to a report of the Chicago Drainage Commission, prepared by Mr. L. E. Cooley, an engineer of that commission. Records of borings showing the elevation of the rock floor have been obtained at the offices of the persons or companies who made them, except in the case of the Princeton artesian well. The record of this well was furnished by Mr. Jacob Miller, President of the Princeton Academy of Science. The Princeton well-boring is here included, since it is near the border of the present Illinois Valley and probably strikes the deepest part of the old channel. We are indebted to Professor J. A. Udden, of Rock Island, for the collection of records of wells at Bureau Junction, Hennepin, Putnam and Henry.

[1] It should be noted that the low water altitudes here given, taken from the report of the Missouri River Commission, average about four feet higher than in Gannett's Dictionary of Altitudes, Bull. U. S. G. S., No. 76. The altitudes given in the table for the Mississippi are from Gannett's Dictionary of Altitudes.

[2] The report of the Missouri River Commission for 1890 contains a description of a gorge 2000 feet or less in width and 60–75 feet in depth, which crosses the valley in an east to west direction, nearly at right angles with its present course.

[3] The river silts and sands extend only to elevation 790 feet. Beneath them is a hard clay seventy-five feet in depth. The description given in the reports of the Missouri Commission do not make clear whether it is a glacial deposit or an earlier formation.

ALTITUDES OF ROCK FLOOR AND PRESENT ILLINOIS.

| Location | Dist. Miles | Low water A. T. | Fall per mile | Rock Floor, A. T. |
|---|---|---|---|---|
| | | Ft. | In. | Ft. |
| Mouth of Kankakee River..... | 0.0 | 485.3 | | 483 ± |
| One mile below Kankakee River..... | 1.0 | 481.6 | 44.04 | 479 |
| Head of Marseilles Pool..... | 11.7 | 477.9 | 3.80 | ? |
| Marseilles Dam..... | 12.7 | 476.8 | | 468 [1] |
| Marseilles, below dam ..... | | 468.8 | 8.59 | 456–468 |
| Foot of rapids ..... ..... | 1.5 | 458.3 | 84.00 | 457 ± |
| Above Ottawa ⅔ mile ..... | 5.3 | 447.9 | 23.54 | 445 |
| Head of rapids..... | 6.7 | 444.9 | 5.37 | 440 |
| Head of pool ..... | 2.6 | 438.1 | 31.38 | 435 ± |
| Peru, at Zinc Works..... | 7.3 | 438.1 [2] | | |
| | | 433.9 | 6.90 | 320 |
| Princeton, in buried channel... | | | | 270 |
| Bureau Junction (Bureau Creek Valley)..... | | | | 340 |
| Hennepin..... | 13.6 | 438.1 [2] | | |
| | | 432.2 | 1.50 | 380 |
| Putnam, two miles from river.. | | | | 340 |
| Henry..... | | | | 355 |
| Peoria (Bigham's artesian well) | 47.4 | 428.9 | 0.84 | 341 |
| Pekin, at City artesian well.... | 10.7 | 427.3 | 1.79 | 325 |
| Beardstown. Artesian wells... | 63.3 | 418.6 | 1.65 | 345 |
| Mouth of Illinois..... | 86.1 | 403.6 | 2.09 | ? |
| Bellefontaine, Missouri. Bridge foundation..... | 17.0 | 402.0 ± | | 295 |
| East St. Louis, Illinois. Bridge foundation..... | 24.3 | 380.0 | | 284 |

The causes for the very low altitudes of the rock floor, and also the slight descent of the present stream below Peru, merit careful consideration, while the irregularities in the rate of descent in the portion above Peru, need a word of explanation.

Taking these up in the reverse order we find the irregular descent above Peru to be plainly attributable to variation in resistance to erosion, presented by the stream bed. The rapids occur where the stream is cutting across hard rock ledges, while the pools occur in the softer strata, between these ledges. This valley, as is well known, once constituted the outlet of Lake Michigan and was then occupied by a stream having much

[1] River raised by dam. The dam rests on rock at 468 feet A. T.

[2] River raised by dam to 438.1 feet. The dam is located at Henry, Illinois, 13½ miles below Hennepin. The altitudes at points below Hennepin are given at the natural level of the river.

greater volume than the present river. This stream effected a great amount of erosion, but its duration was too brief to enable it to cut down its bed in the new portion of the valley, to a uniform slope. Mr. Cooley has well expressed the influence of the strata in his discussion of the old lake outlet:

"The ancient stream carved its grade according to the resisting material, steep in the Niagara limestone to Lake Joliet, steep in the Cincinnati limestone at the mouth of the Kankakee, light through the friable Coal Measures, to the resisting strata at Marseilles, and steep in the St. Peter's sandstone from above Ottawa to Utica, where the water-lime group checked the lakeward extension of the alluvial valley. . . . .

"Below Utica a wide valley in the Coal Measures, narrowing toward the mouth in the resisting rock of the older formations, extends for 230 miles to the Mississippi, with a present fall of about 28 feet (31 feet). The sand and gravel of the ancient stream bed lie deep below the silts and ooze, the spoils of the land through which the comparatively insignificant modern stream struggles to maintain a channel and build up its bed and inadequate grades to present requirements. A wide expanse is there of shallow lakes, bayous, marshes and fens, reed growing lowlands, and low bottoms, which in a true alluvial stream adjusted to its work should be at ordinary extreme high water, but which are but little more than half way there" (Report to Chicago Drainage Commission, p. 2).

Mr. Cooley's words introduce us to a consideration of the cause for the low rate of fall below Peru. If we divide this portion of the valley into small sections, we find interesting contrasts. There is, between Peru and Peoria, a distance of sixty miles, an average fall of one inch per mile. This is distributed as follows:

| | | | |
|---|---|---|---|
| Peru to Hennepin, | 13.6 miles. | Rate of fall, | 1.5 inches per mile. |
| Hennepin to Henry, | 13.5 miles. | Rate of fall, | 1.07 inches per mile. |
| Henry to Chillicothe, | 13.3 miles. | Rate of fall, | .55 inch per mile. |
| Chillicothe to Peoria, | 18.3 miles. | Rate of fall, | .26 inch per mile. |

From Peoria to Beardstown, a distance of seventy-four miles, the average fall is 1.67 inches and from Beardstown to the mouth, a distance of eighty-six miles, it averages a little more than two inches per mile (2.09). Even this, the most rapid rate shown in the lower Illinois is remarkably small, compared with that of

the Mississippi. The fall in that stream in the 222 miles from the mouth of the Illinois to Cairo, being 133 feet, or about 7.18 inches per mile.[1] We seem to have in the lower Illinois Valley a partially obliterated lake in which the outlet has worked its head up the valley to the vicinity of Peoria, with a decrease in slope headwards. Then comes Peoria Lake, between Peoria and Ghillicothe, at the head of which is a silt-filled district, in which the river shows an increase in slope headwards to Peru, the old head of the pool or lake. The only available data concerning the amount of filling is obtained at the Santa Fé bridge at Chillicothe, where it is probably much lighter than nearer the head of the old pool. The bridge foundations are reported to have reached the bottom of the river silts at a depth of thirty feet below the bank, or about twenty feet below the bed, there being coarse sand and gravel at lower depths.[2] A series of test borings along the valley is needed to bring out satisfactorily the condition of the valley bed at the beginning of the present period of deposition.

It is a question whether the lake outlet was adequate to produce a channel with such extremely low grade as this valley presents between Hennepin and its mouth. Another possible factor should be considered, that of a warping of the valley subsequent to this period of excavation.

This leads us to the discussion of the attitude of the floor of the preglacial valley. By reference to the above table it will be observed that the valley floor at Princeton is but 270 feet A. T., while the lowest known point in the valley bottom opposite St. Louis, forty miles below the mouth of the Illinois and 260 miles below Princeton, is 284 feet A. T. or fourteen feet higher than at Princeton. It is barely possible, but scarcely probable, that there exists, opposite St. Louis, a channel sufficiently deep to give a fair gradient for the valley floor from Princeton to St. Louis. A gradient of but three inches to the mile would require a

[1] The distance we have given is about that of the high water stage. COOLEY's report to the Chicago Drainage Commission gives 238 miles as the distance along the river channel. This would reduce the fall per mile to 6.70 inches.

[2] COOLEY's Report to Chicago Drainage Commission, p. 58.

channel sixty-five feet deeper opposite St. Louis than is yet known to us. It is doubtful if the lower end of the Illinois Valley has a rock floor as low as at Princeton. Borings in the middle of the valley at Beardstown reach rock at an elevation seventy-five feet higher than the rock floor at Princeton, though nearly 150 miles below Princeton. Several wells have been made in Beardstown, and they indicate a quite uniform level of the rock floor. It is possible, but hardly probable, that a much deeper channel exists at that point. Wells above Beardstown, at Pekin and Peoria, though situated in each case within one-half mile of the rock bluffs, reach a lower elevation than those at Beardstown before entering rock, while at Peru a well which is apparently in a small preglacial tributary of the Illinois, several miles from the main valley, finds the rock surface at a lower elevation than the wells at Beardstown. We may have, therefore, in this valley, a warping of the rock floor to such a degree that the slope has been reversed above Beardstown.

If we compare the elevation of the rock floor in this portion of the Illinois, with that of the Mississippi a few miles to the west, we find support for the view that this section of the Illinois valley is much depressed. The boring at Sabula, Iowa, 65 miles in direct line from Princeton, apparently tests better than any other boring, the limit of excavation in the Mississippi. The Sabula boring shows the rock floor to have an elevation 429 feet A. T., or 159 feet above that at Princeton. In case the upper Mississippi Valley connected with the valley at Princeton, through the Green river basin, its valley floor would have a fall of nearly 2½ feet per mile, or six times the rate of fall of the present upper Mississippi, and nearly thirty times the fall of the present Illinois just below Princeton.

About 150 miles further down we find no evidence that the Illinois and Mississippi differ greatly in the elevation of their valley floors. Thus wells at Ft. Madison, on the Mississippi, and at Beardstown, on the Illinois, separated by a distance of about 60 miles, and in the same relative position as the Sabula and Princeton borings, show only 20 feet difference in the altitude of the rock floor.

The available data seem, therefore, to point quite strongly to a depression in the portion of the Illinois valley north from Beardstown. To fully establish this depression, it will be necessary to make certain that there is no narrow gorge leading down the Illinois, with a rock floor sufficiently low to correspond with that at Princeton. If the absence of such a gorge were demonstrated by a full series of test borings across the valley at points below Princeton, there would still remain an element of uncertainty in the fact that a local deepening of the valley through glacial agencies may have been produced at Princeton during the ice invasion. We would remark, however, that the valley has a trend transverse to the direction of ice-movement and, therefore, unfavorable for erosion by the ice, or by subglacial streams.

The probability of northward depression in the Illinois valley being so strong, we will refer briefly to a possible cause for such a depression. To the general cause for northward depression, found in the weight of the ice-sheet, we have here an additional cause in the immense amount of drift deposited along the course of the old valley. This valley, from the vicinity of Pekin northward, past Princeton, is bordered by a very bulky moraine, which, for some distance northward from Princeton occupies the supposed old course of the Rock-Illinois. The drift in this region is rarely less than 200 feet, and probably reaches a depth of between 500 and 600 feet north of Princeton, where the moraine occupies the old valley. This weight, unlike the ice-sheet, still continues an obstacle to the return of the valley floor to its former altitude, if not as a direct cause of depression. It may be found that some depression has been produced by it since the date of the lake outlet. If so the very low gradient of this portion of the Illinois would be explained only in part by the greater volume of the lake outlet. Recent warping of the valley may become an important factor.

*The Wabash Valley.*—The few borings of which we have record along the Wabash below Covington, are situated in the middle of the valley and probably test its deepest portion. The altitudes of the valley floor and present stream at points where these borings have been made are as follows:

| | Present Stream | Valley Floor |
|---|---|---|
| Montezuma, Artesian well - | 465 ± ft. | 400 ft |
| Clinton, Coal boring - - | 450 ± " | 370 " |
| Terre Haute, Oil wells - | 445 ± " | 345–360 ft. |
| Vincennes, Artesian well - | 400 ± " | 345 ft. ± |
| Shawneetown, Ill., Oil boring - | 350 ± " | 240 " |

The altitude of the valley floor of the Wabash is apparently somewhat higher than that of the Illinois and Mississippi valleys in the same latitude, the difference in altitude is, however, not very marked.

In the district north from the bend of the Wabash at Covington several borings have been made which show a rock floor lower than those on the Wabash. One boring near Oxford, Indiana, enters rock at the extremely low elevation of 300 feet A. T. A few miles northwest from Oxford, in Iroquois county, Illinois, a boring is said to have reached a depth of 400 feet without entering hard rock. As its mouth is but 660 feet the rock floor here may fall below 260 feet A. T.[1] Unfortunately this record is not so trustworthy as the importance of the determinations of so low an altitude of rock floor would demand. The exact depth is somewhat uncertain and there is a possibility that the soft Cincinnati shales may have been entered near the base and not distinguished from the blue till of the overlying drift. The records of the Oxford borings are apparently trustworthy. The region north from Covington, Indiana, may present such a northward depression, as is exhibited by the portion of the Illinois near Princeton.

A few borings in the east central part of Illinois, nearly midway between the Wabash and Illinois, show a remarkably low rock surface. These may be in the line of a valley discharging southward to the Kaskaskia, or in tributaries of the Wabash or of the Illinois. A well at Monticello, in Piatt county, Illinois, reached a level but 352 A. T. without entering rock. One at Kenney, in western De Witt county, failed to find rock at 358 feet A. T. A boring made at Paxton, in Ford county, entered rock at 350 feet A. T., while one at Odell, in Livingston county, entered rock at 355 feet A. T. It appears from these data that

[1] Geol. of Illinois, Vol. IV. p. 237.

the preglacial channels of east-central Illinois have a sufficiently low depth to correspond with the low altitude at Princeton or at Oxford. These borings which show so low a rock floor all occur in a district very heavily covered with drift. The cause suggested for the low altitude at Princeton may find application in the entire field of heavy drift between Princeton and Oxford.

*The Lake Michigan basin and outlet.*—It is yet to be determined whether the Lake Michigan basin is connected on the south with a preglacial tributary of the Mississippi by a channel so low even as the floor of the Oxford borings. We have already noted that the most probable line for such a connection would be southward from Michigan city to the Wabash, near La Fayette, and thence west to Oxford. But the lowest altitudes found along this line, north from La Fayette, are much above that of the rock floor at the Oxford boring. The boring at Monticello, Indiana, enters rock at 467 feet A. T., that at Winamac at 490 feet and that at North Judson at 497 feet. The lowest altitude yet found near the border of the southern portion of the Lake Michigan basin is 350 feet A. T.

A line following the longer axis of the basin descends from 350 feet at Michigan city to about sea level opposite Racine, then rises above 200 feet A. T. opposite Milwaukee, north from which it descends to 289 feet below sea level, and continues below sea level nearly to the north end of the lake. As the lake bottom is probably coated to considerable depth with glacial deposits and lake sediments, the rock floor will show even greater range.

Cross sections of the basin show interesting variations. In the deep portion of the basin opposite Racine there is very little irregularity. The bottom is as smooth as it is in the southern end where the drift has concealed all the irregularities of the rock floor. East from Milwaukee the lake charts show a single narrow ridge in an otherwise smooth bottom. Between Port Washington, Wisconsin, and Muskegon, Michigan, a cross section presents the appearance of a series of escarpments facing westward like the Niagara escarpment of eastern Wisconsin. The highest points exceed 300 feet A. T. For some distance

north of this line only slight irregularities of bottom appear. But the north end of the basin is very irregular in depth.

The low altitudes of the rock floor in northeastern Illinois and northwestern Indiana seem readily accounted for by a differential crust movement without the aid of glacial erosion. But in producing the variations in altitude displayed by the floor of the Lake Michigan basin glacial erosion was probably an important agency. With fuller light concerning the floors of the great valleys parallel with the lake basin there will probably be developed criteria for estimating, more accurately than is now possible, the effect of each agency which has been influential in the shaping of the lake basin.

*The Ohio Valley.*—Concerning this great eastern tributary of the Mississippi we have space for but a few remarks.

The lower portion of the Ohio valley has received, as yet, very little attention and we have data concerning the altitude of the rock floor at but one point below Lawrenceburg, Indiana, viz, Shawneetown, Illinois, where it is 65 feet below the present stream. At Lawrenceburg, Indiana, and Cincinnati, Ohio, the rock floor is but 50 to 75 feet below low water, or but little below the scour of the present stream. Above these points, so far as ascertained, the rock floor is usually within 30 to 60 feet of the present stream bed until we reach the upper Allegheny, when it drops down rapidly and leads through buried channels to the Lake Erie basin. The northern tributaries of the Ohio, being as a rule deeply filled with drift, are now flowing at considerable heights above the rock floor. The present streams show a much more rapid descent than the rock floors, even where the rock floors slope toward the Ohio. In the headwater portions of these south-flowing tributaries, the rock floor has been found in several instances to slope northward. This fact, together with the occurrence of deeply filled channels, leading across the present watershed, is thought to indicate that the drainage basin of the Ohio has been greatly enlarged, through the influence of the glacial invasions and deposits within the state of Ohio, as well as in Pennsylvania and western New York.

The depth of *preglacial* erosion in the upper Ohio region is a

subject upon which differences of opinion have arisen among the several geologists who have investigated the region; it being maintained by some, among whom the present writer is included, that in consequence of the enlargement of the drainage area by a glacial invasion, a considerable part of the valley has been deepened below the limits of the preglacial rock floor. Others maintain that the deepening occurred shortly before the first ice invasion, during a supposed brief period of higher elevation than the present and is therefore *preglacial.* We can only refer the reader to the literature of this subject as presented by Carll, White, Stephenson and Chance, in the reports of the Pennsylvania Geological Survey, and more recently by Chamberlin, Wright, Foshay, Hise and Leverett, in the *American Journal of Science.*

Reviewing the data of the entire field we find that the valley floors of the Mississippi, Illinois and Wabash were excavated, prior to the first ice invasion, to a depth 50 to 200 feet below the present streams. The southern portion of these valley floors apparently slope southward, with a gradient not greatly different from that of the present streams, while the northern portions are considerably depressed. It seems probable, therefore, that the north part of the Mississippi basin stood relatively, if not absolutely, higher than now prior to the first ice invasion. The portion near the southern border of the glaciated district may have stood no higher than at present. The region drained by the Missouri, on the other hand, seems to have had, up to the time of the first ice invasion, a lower altitude than the present. There seems, on the whole, little evidence that much of the Ohio drainage basin has stood higher. The complications in this valley, resulting from the great increase of the size of the drainage basin, make it difficult to estimate the preglacial altitude, for the enlarged stream would require, independent of altitude, a deeper valley.

## AGE AND STAGE OF DEVELOPMENT OF THE PREGLACIAL VALLEYS.

In closing this discussion a few remarks seem necessary concerning the date of the uplift which inaugurated the channeling

of the preglacial valleys and the stage of development which these valleys had reached when the ice invasion occurred.

The study of physiographic development carried on in the eastern part of the United States through the zealous labors of Davis, McGee and others has brought to light a strong array of evidence indicating that the valley channeling of the region under discussion was not begun until after the close of the Cretaceous, and that it may have been largely accomplished in the latter part of the Tertiary.

It is evident from the sharply outlined valley borders, and other reliefs of the region, that the drainage systems had not reached a stage of senescence, though the size of the valleys, or the the measure of work which the preglacial streams accomplished, is certainly several times as great as that of the post-glacial valleys. The preglacial valleys are not only deeper than the present valleys, but were also excavated, as a rule, in a more resistant material. The accompanying figure, furnished through the kindness of the state geologist of Iowa, serves to show the

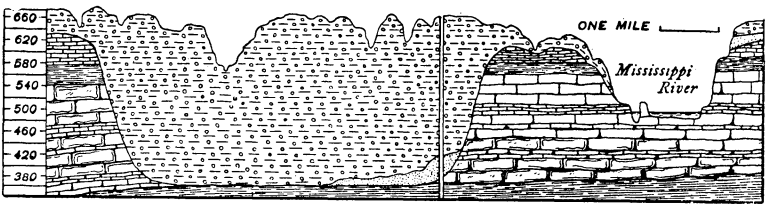


FIG. 1. Cross-section from Sonora, Illinois, to Argyle, Iowa, showing old and new channels of the Mississippi River. [Iowa Geological Survey.]

comparative sizes of old and new channels when cut in material of the same degree of resistance. It would apply equally well in other large valleys of this region, situated outside the limits of the later ice invasion. Within the limits of that invasion, the post-glacial valleys are much smaller than in the older drift territory. Where the present stream follows the preglacial channel in the older drift territory, it has usually removed the glacial deposits throughout the entire breadth of the preglacial valley, leaving only the portion of these deposits that lies below

the level of its scour. The contrast in size of preglacial and present valleys in such cases is not great, though the work accomplished in removing the glacial deposits is no greater than in cutting the narrower valley in the rock, shown in the figure.

In places a preglacial valley is found to carry shelves of considerable breadth, now concealed beneath the present valley bottom, thus at Quincy and St. Louis a rock shelf extends entirely across the present bed of the Mississippi, with an altitude 60 feet or more above the deeper portion of the valley. The following tabular statement of data of the two bridges in St. Louis, furnished by Robert Moore, C.E., serves to show the existence of such a shelf at one bridge and its absence at the other. The Eads bridge is about three miles below the Merchant's bridge. Its west end is at the west bluff, while the west end of the Merchant's bridge is one-half mile from the west bluff. The shelf, therefore, extends at least one-half mile further into the valley than the length of the bridge.

ELEVATIONS OF ROCK FLOOR AT ST. LOUIS BRIDGES.

| | Eads Bridge | Merchant's Bridge |
|---|---|---|
| Bed Rock Pier 1, West Shore | 375.71 feet | 341.33 feet |
| Bed Rock Pier 2 | 341.91 " | 342.05 " |
| Bed Rock Pier 3 | 293.71 " | 339.93 " |
| Bed Rock Pier 4, East Shore | 284.30 " | 334.90 " |
| Extreme high water | 420.29 " | 422 (?) " |
| Extreme low water | 378.97 " | 380.50 " |

It is probable that such shelves as these are remnants of an old valley floor. Their full breadth is not known, hence we cannot judge whether they are mere fringes on the border of the deep channel, or are of such breadth as to reduce greatly the width of the deep channel. The data from the St. Louis bridges cover only about one-tenth, while those of the Quincy bridge cover one-sixth the breadth of the preglacial valley. If the shelves greatly reduce the width of the valley, their bearing upon the valley's history—its stages of uplift, etc.—may prove to be of considerable importance. It is as yet not certain whether the valley was deepened regularly during continuous

uplift, or whether it was subject to periods of deepening, between which were periods of equilibrium, when the force of the stream was expended in broadening the channel.

An important feature connected with the development of the preglacial drainage of this region has received thus far but little attention, namely, *variations in stage of development* displayed by the drainage lines in different parts of the Mississippi basin. My attention was first called to the matter when studying southern Illinois, in the autumn of 1892. It was found that there is a great scarcity of deep buried valleys, compared with their number further north. It is only at rare intervals that a well on the uplands fails to strike rock within a few feet of the level of the upland plain. The main preglacial valleys of this region are cut to but moderate depths, seldom showing an excavation of more than 100 feet below border districts. Upon discussing this matter with Professor Chamberlin it was found that he had noted a similar feature in the unglaciated part of Missouri, near Sedalia. The greater part of the surface is unfurrowed by drainage lines. The few which occur have reached only an adolescent stage of development. The appearance is as if an uplifted base leveled region had been subjected to erosion for an insufficient time to allow well developed systems of drainage to be inaugurated. Further north (and especially in northern Illinois and the driftless area of Wisconsin) the preglacial systems had dissected the uplands quite thoroughly. though the altitude is not much greater than southern Illinois and scarcely so great as the region around Sedalia. From what is now known, it seems probable that the northern districts suffered uplift long before the southern. A thorough investigation of this matter will doubtless bring out a very interesting history, showing an increasing extent and degree of uplift proceeding from certain centers of upheaval, by which the peneplain of the Cretaceous and early Tertiary periods rose and became transformed into the more or less deeply channeled uplands of the early Pleistocene.

FRANK LEVERETT.

Denmark, Iowa, May 23, 1895.